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Photographic Location in the Beavertail Area of Narragansett Bay from Fixed Stations on Shore

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Summary

Installations and equipment for the photographic location of ship movements and splashes in the Beavertail Point area of Narragansett Bay are described. The use of microfile film made possible the adequate recording of such events on the single frame of 35mm. motion picture cameras. A transparent collimated clock is described which, when constructed, should provide a direct photographic record on each frame of the time of exposure, and would, therefore, provide the means for identifying synchronous frames on two cameras which are set up for triangulation purposes. The fundamental problem of associating an object in these photographic records with its map location is discussed. The simple methods used during the past summer for this purpose are described and a more elaborate projection device is suggested ~~which~~ which would perform this operation rapidly and accurately. The limitations imposed on such photographic location by low visibility, fog, and darkness are discussed as well as the disadvantage inherent in the small angle of view of the motion picture cameras.

Photography is basically a device for the collection, storage,and presentation of information. Its primary advantage as a tool for research lies in the rapidity with which information can be collected,the automatic way in which it takes care of the storage problem,and the enormous number of items of information which it can gather simulaneously. This project was set up with the object of giving proper attention to these possibilities in the work being undertaken at Beavertail. To date attention has been almost exclusively concerned with the field of photogrammetry although other possible applications of photography have not been entirely ignored. It is inevitable that a project of this sort,working with limited personnel and budget,and faced with the necessity of accomplishing specific assigned tasks on schedule,should primarily concern itself with the adaptation of already existing techniques. A limited number of new ideas have evolved,however,which belong rightfully to the category of research,and will be considered in proper order.

The primary task assigned was that of recording and

locating events such as splashes and ship movements in the waters about the Beavertail Point installations. Nine permanent stations were established, six on Conanicut Island, two in the Newport area of Rhode Island, and one at Fort Varnum on the mainland. Since the opprations of the past summer were concentrated in the West Passage and the area south from Beavertail Point, only five of these installation were used to any considerable extent, Beavertail Point, Prospect Hill, Fort Getty, Fort Varnum, and Brenton Point. Two four-inch steel pipes were set in concrete at each of these positions for mounting the camera and the theodolite (or transit) respectively, Plate 1. Two 35mm. Bell and Howell motion picture cameras were acquired for this work. Subsidiary equipment included single frame advance mechanisms and intervalometers, which permitted the automatic exposure of single frames at any desired interval between 1/10 sec. and 4 min. This single frame equipment could however, be used only where 110-volt A.C. power was available. Exposures of the two cameras could be synchronized electrically where a telephone line connected the two locations. Where such lines did not exist they

were operated manually on verbally transmitted radio signals. Where A.C. power lines were not present (Brenton Point,e.g.) the spring drive of the camera was utilized in short bursts at one of the normal sequence rates between 8 and 48 frames/sec. Indentification of simultaneous frames was achieved by properly interspersed blanks, inserted on radio signals.

In order to increase the amount of detail which could be recorded on the rather small frame (ca.16x22 mm.) microfile film was adopted with a resolution of 180 lines/mm. as against 95 lines/mm. for a conventional film such as Plus-X Pan. There was thus available ideally a 4000 line picture and a resolving power of 1/5 of a minute of arc when using a 10 cm.camera objective. This innovation proved highly successful,records of splashes and ship positions being recorded with a precision approaching that of a visully operated transit. The relatively low speed of the microfile film was adequate under all operating conditions encountered, even permitting the use of a K2 or G filter for increasing contrast under poor atmospheric conditions.

The limited latitude of the microfile film also proved adequate for the low contrast over-water subject material which we wished to record. Processing time was considerably shortened by the thin emulsion of the microfile film. This demonstration of the utility of microfile film for such work can be considered as one of the positive accomplishments of the project during the past season.

The ready identification of synchronous frames,a fundamental necessity for the position location of moving targets, was not so successfully achieved. Plans were laid in the Fall of 1952 to equip the cameras with clocks which would place on each frame a record of the exact time of exposure. This is, of course,not a new idea. A number of photographic recording instruments, such as the so-called balloon theodolite, are provided with such recording devices. All are, however, very special instruments,most of them so heavy as to require permanent installation on a particular location,and all of them complicated and expensive. The simplest way of including time in a photograph is,of course, to place an ordinary clock in field of view. This method is feasible for many laboratory installations, but is out of the question

for photomicrography, and is seldom entirely satisfactory in photographing distant objects owing to limited depth of field.

The present approach was to utilize a transparent collimated dial, illuminated by skylight, thus independent of any source of power for illumination, and providing an exposure which is automatically in accord with the outdoor lighting conditions. This record was to be brought into a suitable position on the film by a beam-splitting mirror inserted in front of the camera lens. The design requirements [redacted] rather exacting. The size of the dial area to be photographed was determined by the diameter of the clock movements, whereas the size of the photographic record was limited by the area of the film which could be allocated for this purpose. The prototype model, constructed during the winter of 1952-53 in the Brown University shop, utilized a Telechron movement, which necessitated a rather large dial. It is easily shown that the lateral magnification of a collimator-camera lens combination is equal to the ratio of the focal length of the camera lens to that of the collimator lens.

This called for a long-focus (20")collimator lens to reduce the image on the film to reasonable size. In the interest of compactness the optical path was folded by use of three front-surface mirrors in addition to the beam-splitter. The diameter of the collimator lens had to be at least as great as that of the largest camera lens to be used if the maximum aperture was to be preserved. The prototype model proved rather clumsy to mount on the levelling table of the camera,and in the interest of economy was constructed without adequate means for controlling the exact position of the time signature on the picture frame. It was redesigned to utilize a somewhat smaller spring-operated airplane clock, which permitted some shortening in the focal length of the collimator lens, a reduction in the number of fixed mirrors to two, and the incorporation of suitable mechanisms for adjusting the location of the signature on the film, a very important consideration if the camera was to be adapted for use with more than a single objective, Fig. 1. It should be possible to install the proposed model efficiently on the present levelling table. The precise mechanical construction necessary for an optical system of this sort is time-consuming and expensive, and

present plans have not progressed far beyond the drawing board stage. Some such device is, however, an essential ingredient in any triangulation system. It provides the practical answer to camera synchronization, and adds time to the permanent record of all operations.

The final problem, in some respects the most interesting one which has been attacked in the present project, is that of associating an object in the photograph with its grid coordinates on the map. Extremely complex systems have been devised in the field of aerial cartography for this purpose, the one most widely used in this country today going by the name of "Multiplex". The present problem is different in a number of respects. The complexity introduced by the necessity of recording topographic relief and correcting for airplane (or camera) tilt are not present. In fact, our problem is essentially a two-dimensional problem. On the other hand, the positions from which the two photographs are taken in general more widely separated, and the records cannot be analyzed by a stereoscopic viewing system. It was apparent very

early in these experiments that measurements on the very fine though tiny records provided by the motion picture cameras were capable of yielding the necessary information for adequate position location. The basic principles of geometrical optics insured that for well-corrected objectives the angles subtended by all pairs of image points from the rear nodal point of the taking lens were equal to those subtended by the corresponding objects from the camera position. The same is true for any enlarged projected image when viewed from a point on the axis of projection which is at a distance equal to the product of the lateral magnification and the focal length of the taking lens. This distance is known as the focal length of the print or of the projected image as the case may be. From such angles, measured on the two photographs, the location of the object on the map grid can be determined either by graphical construction or by a relatively simple calculation.

In much of the work carried out during the past summer the immediate objective was a comparison between photographically determined positions and those resulting from the use of theodolites or other devices. For such a purpose, the angles themselves or the grid locations

obtained by direct measurement with a protractor on the map were adequate. With this end in view precise panoramic photographs were made from each observation post, a large number of prominent landmarks on the horizon were selected, numbered, and accurately located by transit measurements. The motion picture frames to be analyzed were projected on a vertical screen in the projection room, and the distance (usually small) from the nearest useful landmark was measured by a suitably mounted steel scale on the screen. Because of the smallness of the angles involved these distances, though actually proportional to the tangents of the angles measured from the projection axis, were very nearly proptional to the angles themselves, and minor corrections were made by reference to simple tables. This analysis procedure was simple and expeditious. The microfile film was taken from the cameras, processed and dried in less than half an hour, carried to the projection room, and individual measurements made on the screen at the rate of perhaps one a minute. The results, as shown by direct comparison with transit measurements, could ordinarily be relied on to an accuracy of something like 2 minutes of arc.

From the very outset of this work we have felt that it was incumbent on us to look into the possibility of

a more direct association of the photographic record with grid coordinates. We early proposed to ourselves the question, " Is it possible to project the camera record directly on the map grid in such a manner that the object under observation shall lie at the correct map location?" There is no longer any doubt that this can indeed be accomplished if the demand for it justifies the instrumental construction required. The fundamental geometry has certain features of simplicity which are shown in Fig. 2. CD is the image plane, which is to coincide with the map grid. AB is the film to be projected, F_1 and F_2 are the principal foci of the projection lens, and l is the focal length of the projected image. If all image points are to subtend at C the same angle which the corresponding objects subtended at the camera location, it is necessary and sufficient that

$$\sin\theta = F/f$$

where f is the focal length of the taking lens and F is that of the projection lens. This requires that the focal length of the projection lens shall be less (from a practical standpoint considerably less) than that of the taking lens. All image points will be in correct focus if

$$\tan\phi = \tan\theta/M$$

where M is the lateral magnification of the enlarged image on the axis of projection. This projection system amounts to a transformation of the rectangular image on the film to a trapezoidal image on the map grid.

In its ultimate development such a system would call for two non-interfering projectors,one for projecting the film from each of the two observation points. The condition of non-interference probably requires that the projectors shall be mounted on opposite sides of a translucent grid;and to avoid confusion should project in contrasting colors. Each projector must be capable of all possible motions parallel to the plane of the grid,and should be provided with a simple supplementary optical system for projecting a sharp crossline on the point C,which must coincide with the map location of the observation post. Each projector must be capable of rotation about the vertical axis through C,and should be capable of motion along the line F_1C. This, in turn should be geared to a focussing motion of the film carrier AB. All of these motions are mechanically possible,mutually consistent,and are

all to be found in one or another of present-day optical instruments.

Once such a device is constructed, the process of locating any object in its proper position on the grid would consist of three preliminary operations on each projector (which would not have to be repeated in any sequence of measurements in which the camera position was unchanged), followed by a single operation on each projector for each individual object location. The procedure would be as follows: One known landmark would be required on each frame. Each projector is moved about in the horizontal plane until its locating cross-line coincides with the appropriate observation post. It is then swung about the vertical axis through C until the image of the landmark is in line with its grid position. This angular setting is effected by raising or lowering the projector along the line CF_1 until the image of the landmark coincides with its grid location. The angular setting of each projector is now locked until such time as a changed position of the camera requires a resetting. The image of each object in the photograph will now lie on the line joining C and the correct map location. It can be brought into coincidence

with the map location by moving each projector along the line CF_1 until the images formed by the two projectors are in coincidence.

A simplified version of this ultimate system which permitted an experimental test of its essential elements was constructed during the past winter in the Brown University shop. It was used to a considerable extent during the Beavertail operations of the past summer, and proved basically sound. Because of the cost which would have been involved in the complete construction, a single projector for carrying out the trapezoidal transformation was constructed, and a considerable number of actual film transparencies were made with it, Plate 2. Non-interferring frames for holding these transparencies and designed to be rotated in ball-bearing sockets about any of the observation posts were also constructed in the Brown shop, Plate 3. Position location was determined by the intersection of cords attached to the bearing of each frame and passing over the image to be located. A description and photographs of this equipment were published in a technical memorandum early in the past summer.

On account of space limitations it was never possible to install the original projector in the Beavertail darkroom, but an alternative device suitable for installation on the Omega enlarger already in the Beavertail darkroom was constructed and proved entirely satisfactory, Plate, 4. A unique feature of this device was the utilization of an easel, designed by the Kodak Co. for three-color printing, which incorporated a very precise method for positioning the film and a vacuum system for holding it in the proper plane.

The trapezoidal transformation used in this system is very favorable in so far as accidental errors in positioning the negative film in the projector are concerned. The horizon line is perpendicular to the direction of transit of the 35mm. film in its carrier, and any displacement of the film from its anticipated location in this direction introduces no error. A sidewise displacment (parallel to the horizon) does introduce a second order error which might be appreciable where the angle between landmark and object is large. It should be possible, however, to construct the film carrier in such a way as to prevent any significant motion in this direction.

We have thus far been concerned with the manner in which the basic geometry of well-corrected lens systems permits the recovery of geographical position from simultaneous photographs taken from suitable triangulation positions, and with the equipment of this sort which has been used in the Beavertail operations of the past summer. These operations have disclosed not merely some of the advantages of such methods but also a number of weaknesses. Some of these weaknesses are inescapable, such, for example, as the limits imposed by fog, thick haze, and night. Others can be overcome by better instrumentation. Outstanding in this latter category are the difficulties caused by the lack of suitable landmarks to the south and south-east of Beavertail Point. We tried to meet this problem by installing temporary range poles within the field of view of the camera, but such improvisations were never so satisfactory as conspicuous natural landmarks. It is clear that an altogether satisfactory system should include an accurate divided circle on the camera mount, equipped with a vernier of the same degree of precision as that present in a good transit. If the reading of this scale could be recorded along with the time on each frame of the film, it would greatly

facilitate the whole process of analyzing the record. This is not a new suggestion, as it constitutes an integral part of the photographic theodolyte already in use by the navy.

Experiments with infrared photography for overcoming the handicap imposed by haze have not been too encouraging. Apparently the water vapor particle size ordinarily present at sea level is not very effectively penetrated by the infrared wave lengths to which ordinary infrared film is sensitive. These infrared emulsions also proved disappointingly poor as regards granularity,resolving power, and speed. Emulsion improvements may, however, change this situation for the better any time. Even with the infrared film already available, some advantages were discernable under particular atmospheric conditions. The use of photography at night is by no means to be ruled out, as the movements of friendly ships equipped with mast-head beacons (perhaps infrared) could,be very effectively followed photographically. The process of tracking such a ship by night could be even simpler and more economical than is possible by day, owing to the fact that a consider-able number of exposures would be possible on a single frame.

One weakness of our equipment had to do with the relatively narrow field of view (about 12° when using the 10cm.objective). It was not always easy to keep a fast-moving object such as an airplane satisfactorily in the camera field. On the other hand, the accuracy of position location depended on the resolving power of the system, and this depended both on the emulsion resolving power and that of the camera objective. For a given emulsion such as micofile the precision of the angular measurement is proportional to the focal length of the lens used, and the 10cm. objective was chosen in order to achieve what we believed to be the desirable accuracy of measurement. Actually we never approached practically the theoretical limit anticipated, and it is possible that a 5 cm. objective might yield sufficient accuracy and at the same time nearly double the useful field. For following the movement of ships the small angle of view proved no handicap, and the motion picture cameras with their single frame attachments and the 10cm. objectives proved almost ideal. The greatest disadvantage of the present equipment was encountered in recording splashes which might occur on short notice over a rather lamge area. For such a purpose the advantages of a long

focal length with its consequent precision and a wide field of view could both be achieved by recourse to a larger film size. The only cameras already in being which combine large film size with the possibility of a long sequence of exposures are aerial survey cameras. Their use is definitely indicated for monitoring a large ocean area for splashes. A camera adapted to handle large rolls of 70mm. film in much the same manner that our cameras handle 35mm. film is a development to be devoutly desired particularly if microfile film could be made available in this larger size.

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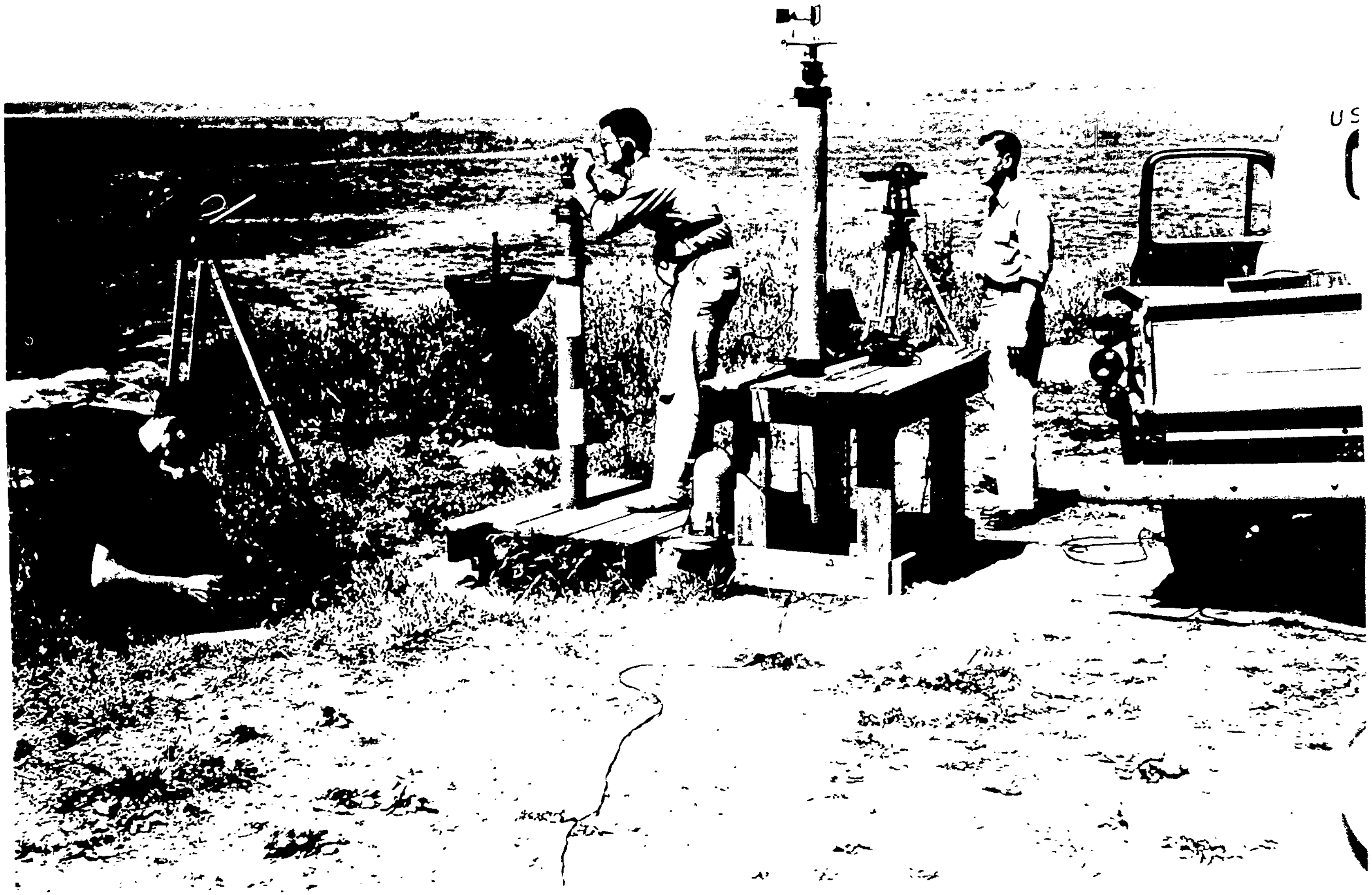


FIG I BEAVERTAIL POINT PHOTOGRAPHIC INSTALLATION

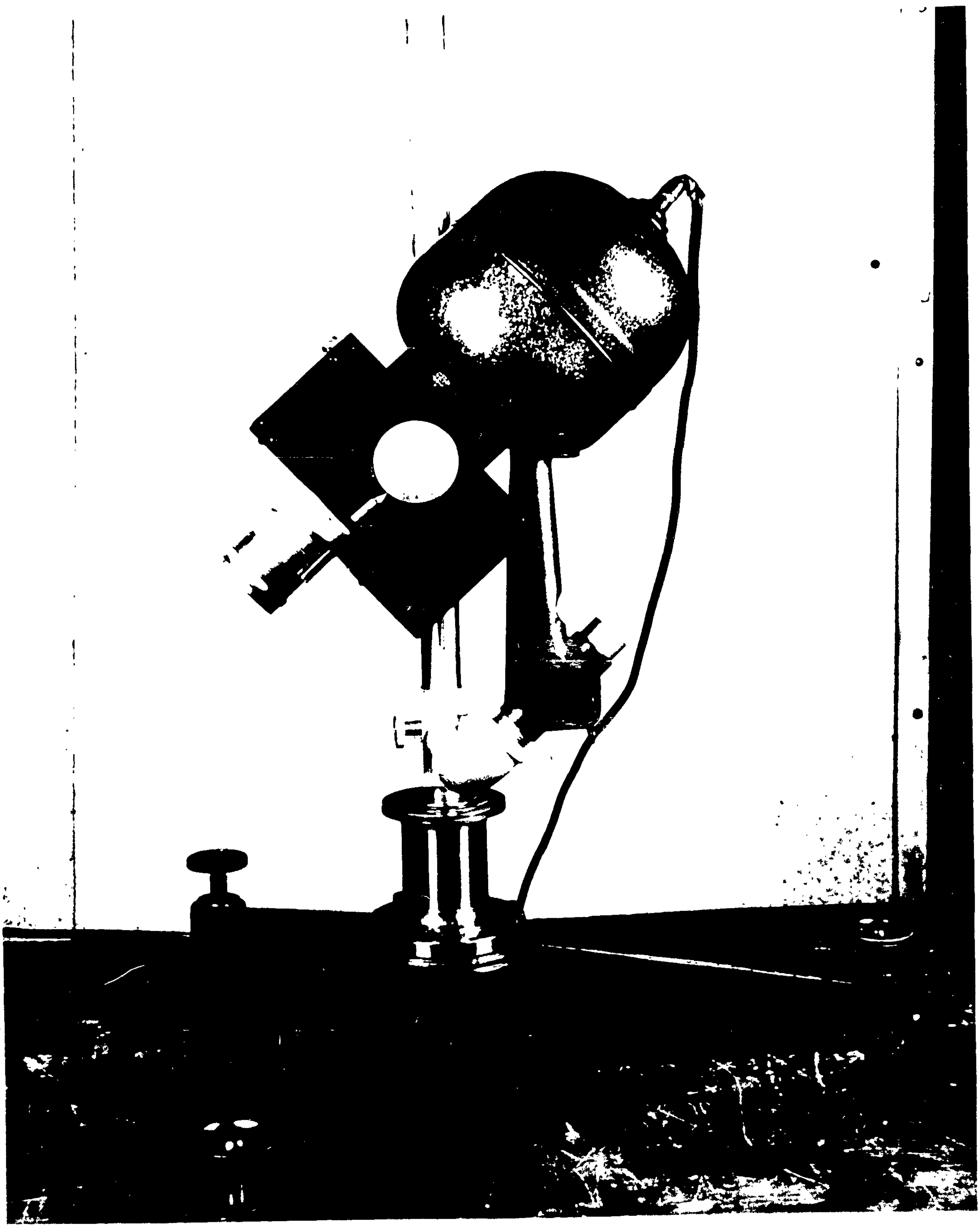


FIG. 2 PHOTOGRAPHIC ENLARGER FOR MAKING DISTORTED PRINTS

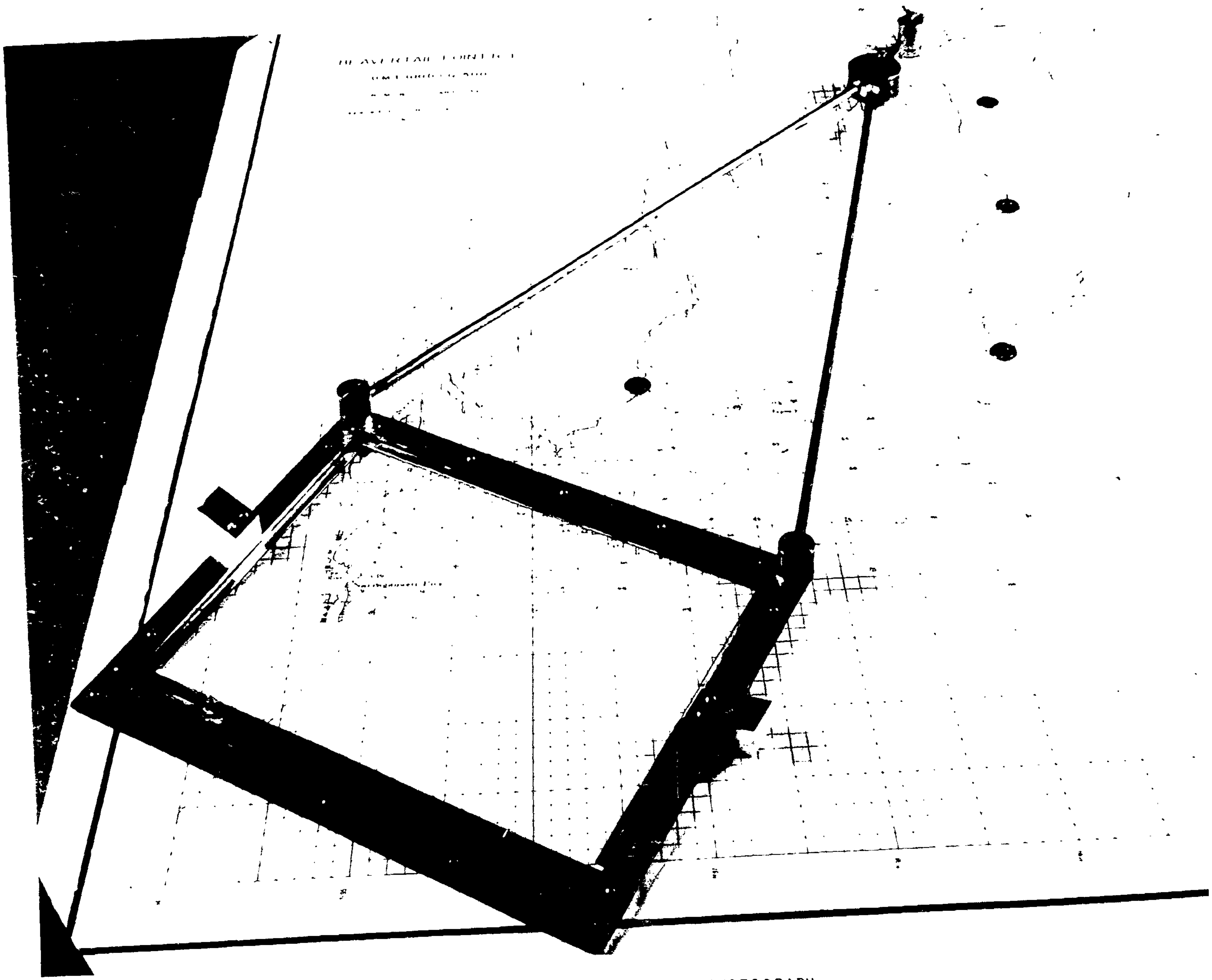


FIG 3 DRAFTING INSTRUMENTS FOR LOCATING MAP POSITIONS FROM PHOTOGRAPH

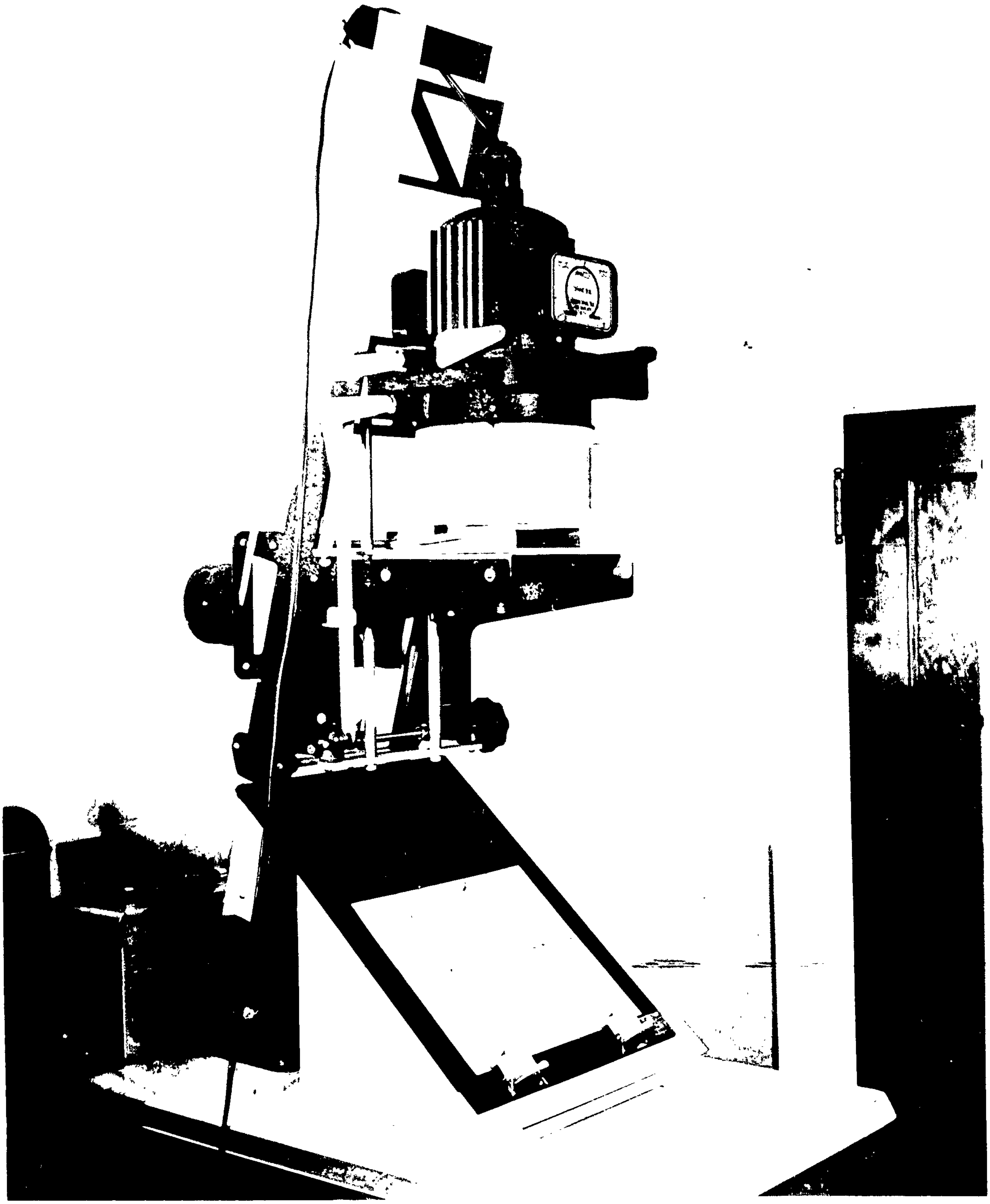
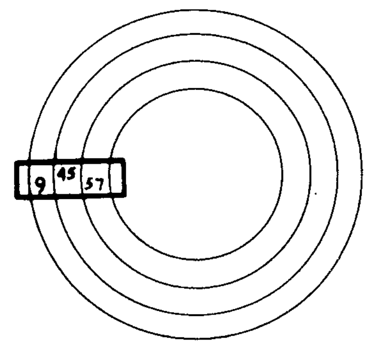
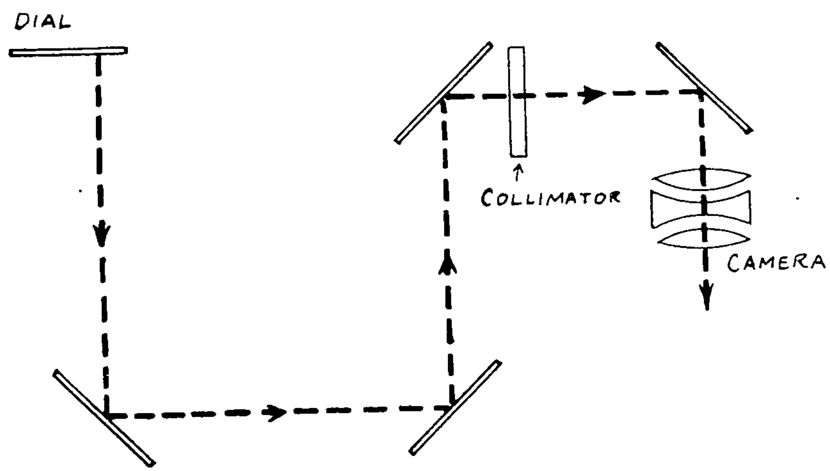


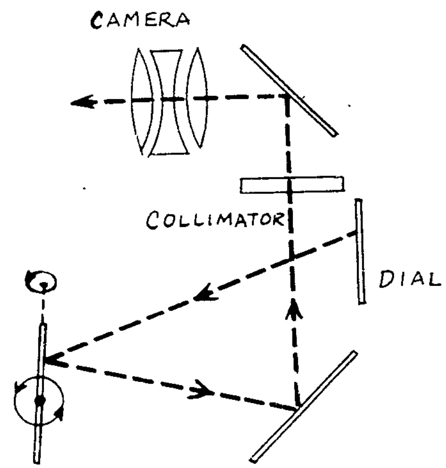
FIG. 4 IMPROVED MODEL OF PHOTOGRAPHIC ENLARGER FOR MAKING DISTORTED PRINTS



CLOCK DIAL



PROTOTYPE MODEL



PROPOSED MODEL

FIG. 1

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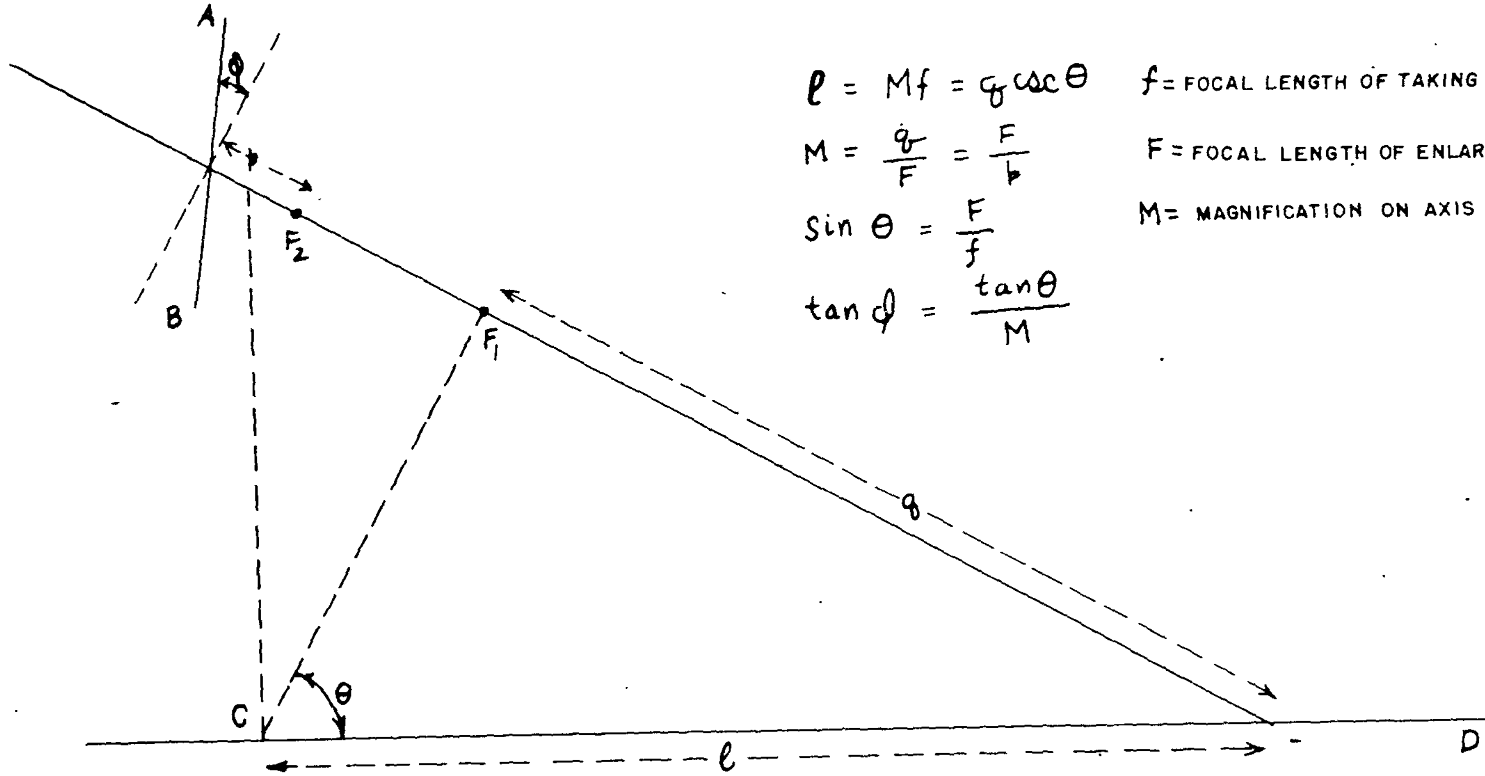

$$\ell = Mf = q \csc\theta$$

$$M = \frac{q}{F} = \frac{F}{p}$$

$$\sin\theta = \frac{F}{f}$$

$$\tan\phi = \frac{\tan\theta}{M}$$

f = FOCAL LENGTH OF TAKING LENS

F = FOCAL LENGTH OF ENLARGING LENS

M = MAGNIFICATION ON AXIS

FIG. 2

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